# Tracking Medical Devices using TCSPC Imaging

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The arrival time difference between near-infrared early arriving photons and their more diffuse, later-arriving counterparts allows location of a pulsed light source deep in tissue by monitoring light passage through the scattering media in a time-correlated fashion.
With time-correlated single photon counting (TCSPC) imaging, nasogastric and endoscopic tubes have been located in clinically relevant models.
On the bench experiments using models, notably ovine lungs, as well as full-sized pig and cadaver models have been used to explore this technique.

## 1 The Challenge: Deep Tissue

- Optical light scatter and absorption in tissue make imaging challenging
- Location of medical devices such as nasogastric feeding tubes normally utilises X-ray imaging

- **Pros**: Great imaging resolution and accurate device location
- Long established technique
- Easily interpreted

- **Cons**: Requires portable x-ray machine or patient relocation
- Harmful, especially for infants
- Misinterpretation of X-ray is leading cause of misfeeding

## Application: Reduced device misplacement

- Misplacement of nasogastric feeding tubes is a well recognised problem
- Deaths associated with misplaced feeding tubes occur regularly, usually attributed to underlying illness with no consideration of death due to tube insertion[2,3]

- **Can we locate these devices using alternate real-time techniques?**
- **Can we exploit optical wavelengths for device location in deep tissue, low-light, clinically relevant scenarios?**

## 2 The Solution: TCSPC Imaging

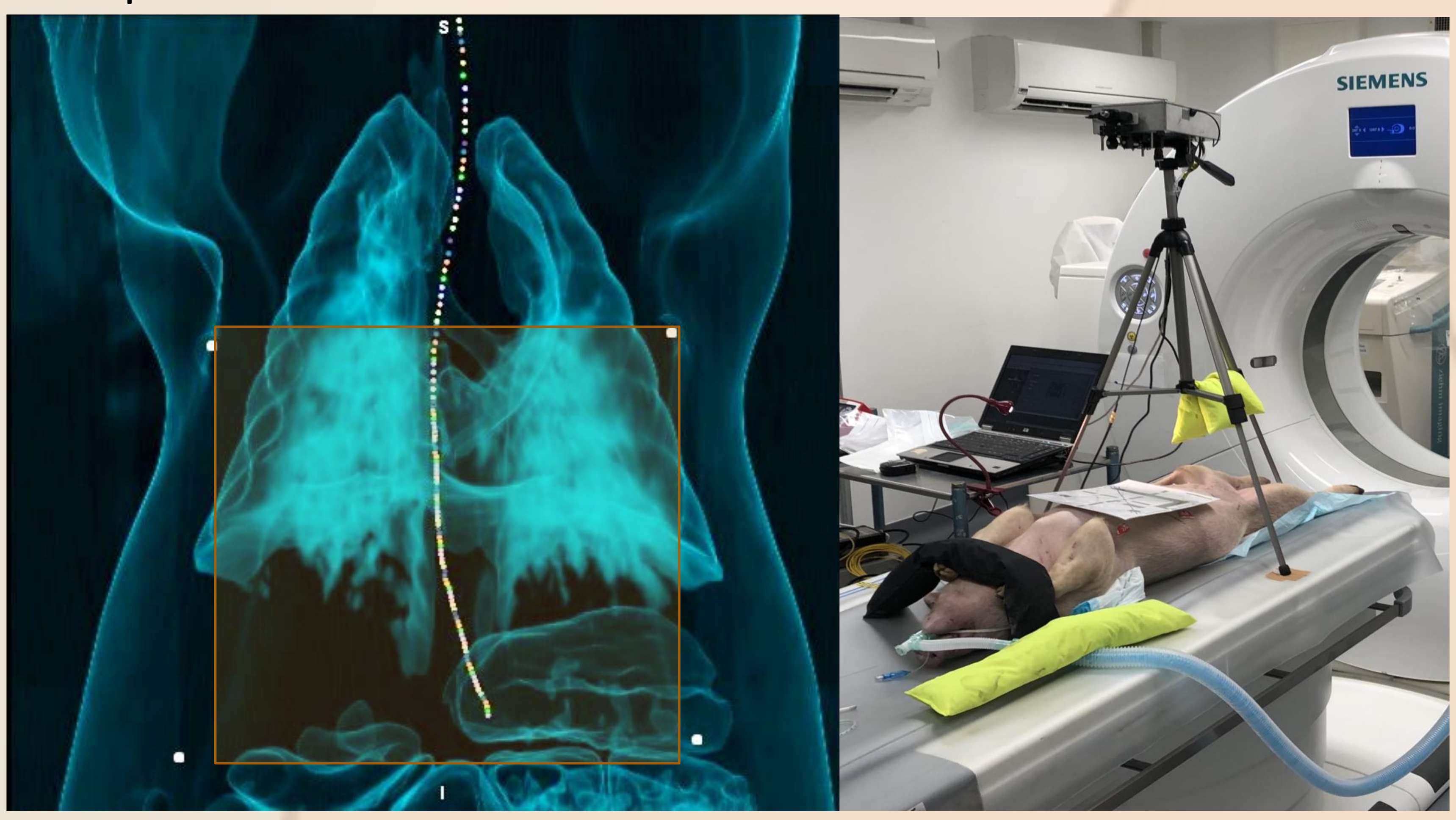
- Device location deep in tissue using NIR time-correlated imaging has been displayed in Tanner et al. (2017)[1]
- NIR optical window (≈650-900nm), light can be transmitted and detected through tissue 10cm+ thick
- SPAD detectors can be used to detect low level light
- Can measure arrival time difference between heavily and minimally scattered NIR photons in a time-resolved manner
- Offers spatial information about the location of the light source

**Using our imaging system, NG feeding tubes and other medical devices can be located.**

## 3 Testing: Clinical Models

- Pig and cadaver models have been used*

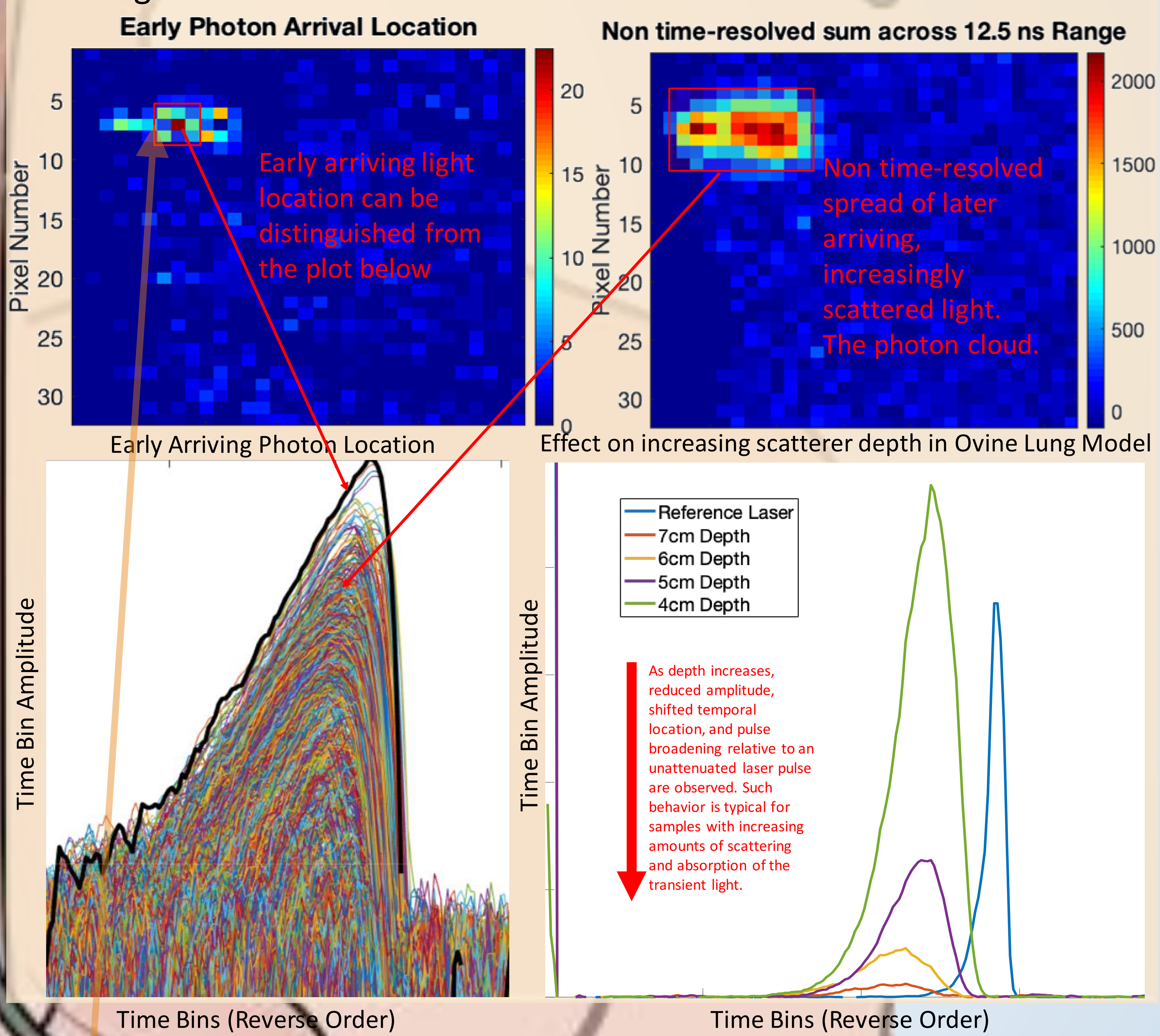
- We receive light from medical devices placed by a clinician at depths **≥8cm**




**Left: CT Verification Scan, Right: Experimental setup, MegaFrame 32 imaging system placed over the patient, creating an effective field of view of ≈ 30cm²**

## 4 Tube Location Example: In ICU Scenario

- A fiber is packaged within the feeding tube to carry pulsed NIR light which is isometrically scattered from the distal end of the fiber
- By imaging the optical transient signal of the light passage, we can locate the light source



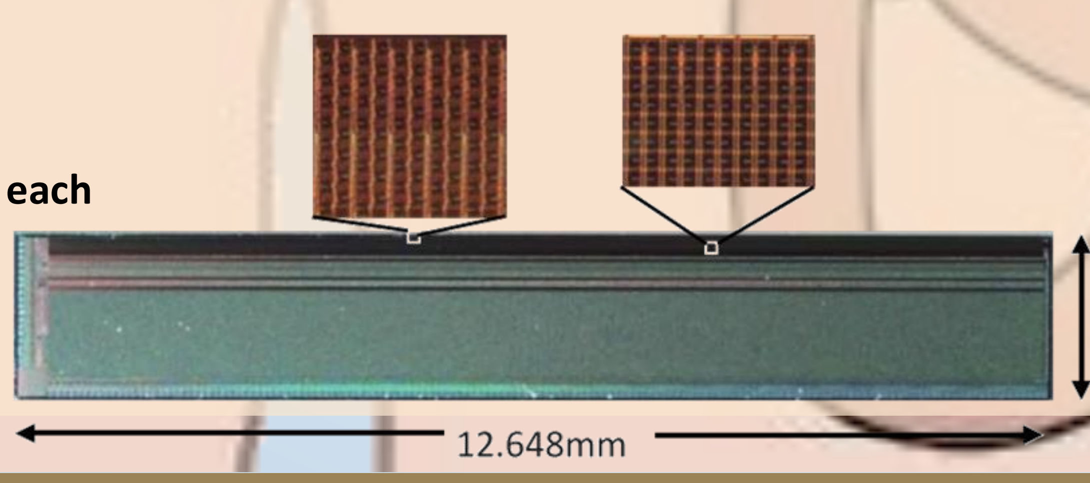

## 5 Future Improvements: Sensor and Probe Hardware

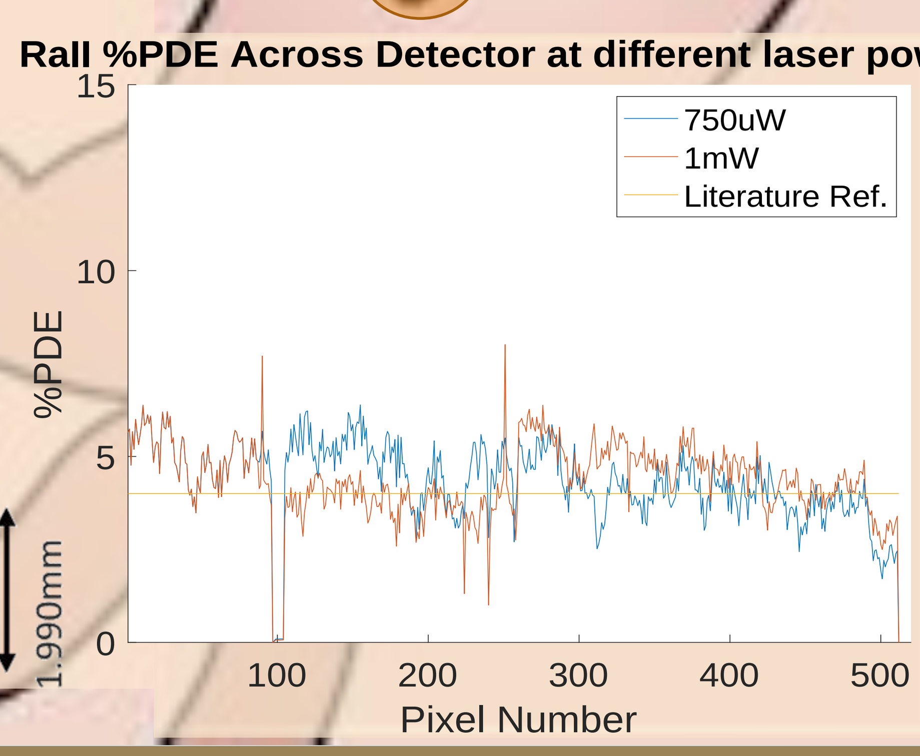
- Bespoke multi-point emission fiber, machined in house at Heriot-Watt's Photonic Instrumentation Group, to track the fibre length
- Developing on bench phantom models for testing and tissue characterisation

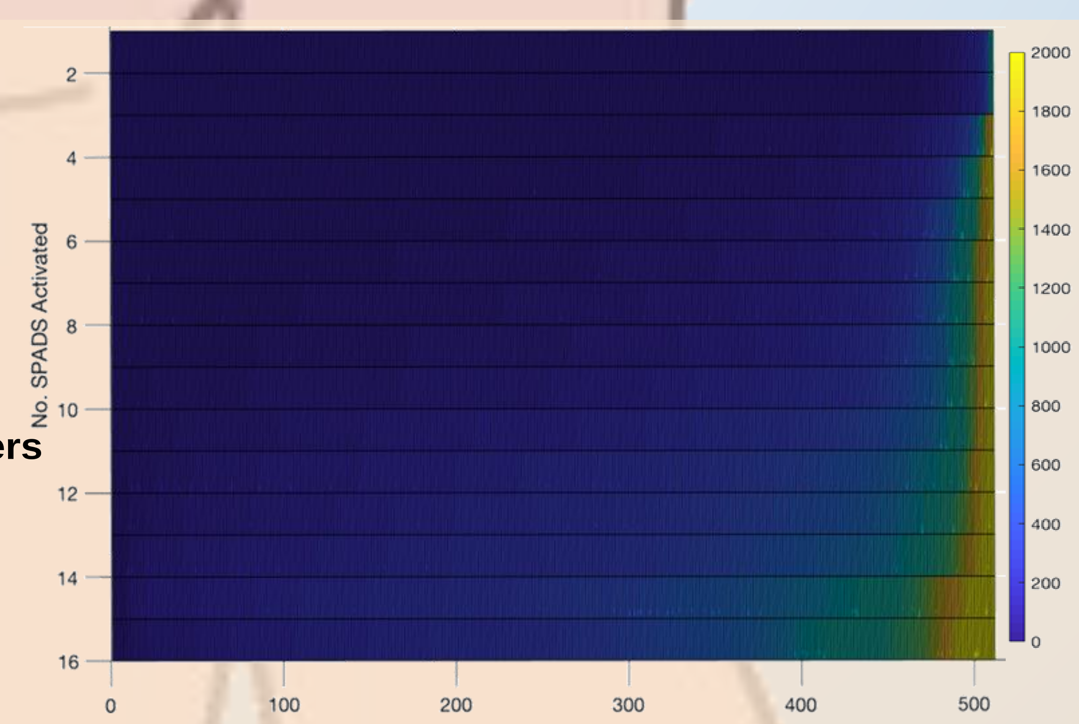
- Implementation of '**Ra-II**' CMOS line censor technology with improved detection efficiency and spatial resolution
- The Ra-II sensor[4], is a 512x1 SPAD line array
    - (Proteus & Systems and Sensors Group at the University of Edinburgh)

- Ra-II will greatly improve the sensitivity of the technique, reducing acquisition times
- Creating a line scanning camera, 512 pixel x scan positions

**The RaII Line Sensor – 512 Pixels, 16 SPADs per pixel, each SPAD 11.98μm²**




**Left:** Experimentally obtained detection efficiency for the RaII sensor, with reference level from literature[4]. We hope to obtain 4-5 time improvement in system efficiency relative to the current detector system, the MegaFrame 32.

**Above:** Dark counts per second across the RaII sensor with changing number of SPADs activated per pixel. By monitoring and understanding the number of extremely noisy pixels, we can remove and replace them from our data.

[1]M. G. Tanner, R. R. Thomson, et al. Ballistic and snake photon imaging for locating optical endomicroscopy fibres, Biomed. Opt. Express 8, 4077-4095 (2017).
[2]A. L. Smith, et al. Deaths associated with insertion of nasogastric tubes for enteral nutrition in the medical intensive care unit: Clinical and autopsy findings, Baylor University Medical Center Proceedings 31 (2018) 310.
[3]S. Prabhakaran, et al. Nasoenteric Tube Complications, Scandinavian Journal of Surgery 101(2012) 147
[4]A. T. Erdogan et al. A CMOS SPAD Line Sensor with Per-Pixel Histogramming TDC for Time-Resolved Multispectral Imaging, IEEE Journal of Solid-State Circuits 54 (2019) 1705.
*In conjunction with the University of Edinburgh ran Dryden Institute at the Large Animal Research and Imaging Facility, and the University of Dundee facility CAHID